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AGRICULTURAL EXPERIMENT STATION

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SUCCESS OF TREE PLANTING On Strip-Mined Areas In West Virginia

by
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Success of Tree Planting on Strip-Mined Areas in West Virginia

JAMES H. BROWN

Introduction

SURFACE mining of coal is not new in West Virginia. Stripping operations began on a small scale in the State prior to World War I. However, it was not until the big demand for coal in the early part of World War II that these operations started on a major scale. Today, spoil banks are a common sight in West Virginia, with nearly 70,000 acres of land in 36 of the State's 55 counties directly affected by strip mining.

Initially, spoil banks are bare of vegetation. Increased washing and run-off of water from these bare areas may result in erosion of lower lands, stream pollution, and landslides and slips. Such occurrences may affect a much larger area than that directly involved in the stripping operation itself. Revegetation offers the most practical means of stabilizing strip-mined lands and returning them to a productive condition.

Since 1945, West Virginia has required that strip-mined lands be planted or seeded with trees, shrubs, grasses or vines (**Acts of West Virginia Legislature 1945** and **Acts of West Virginia Legislature 1959**). Approximately 50,000 of the 70,000 acres of strip-mined land in the State are covered by the provisions of these laws.

Planting of tree seedlings has been one of the most commonly used methods of revegetating spoil bank areas in many states. For example, Boyce and Nebbe (1959) reported that nearly 12,000 acres of forest plantation had been established on strip-mined areas in Illinois, while the Central Pennsylvania Open Pit Mining Association (1959) reported that over 60 million trees had been planted on stripped lands in Pennsylvania. In West Virginia, direct seeding of black locust[1] has been the most commonly used method of reforesting strip-mined lands. The effectiveness of this practice in providing stabilization and cover on spoil banks was reported in an earlier study by Brown and Tryon (1960). Only a relatively small area of strip-mined land in West Virginia has been revegetated by planting of tree seedlings.

[1]An index of technical names, arranged alphabetically by common name, is included in the Appendix. Technical names follow Little (1953).

The purposes of the study reported here were: (1) To evaluate the success of tree plantings on spoil bank areas in West Virginia; and (2) to study the effects of various site factors on the establishment and growth of tree seedlings planted on strip-mined areas.

Procedure

From records made available by the State Agriculturist of West Virginia and the United States Department of Agriculture Soil Conservation Service, a list was compiled of all strip-mined areas in West Virginia on which trees had been planted from two to twelve years previously. This list comprised over 100 individual spoil bank areas in 18 counties. Because the total area involved in these plantings was relatively small, it was decided to examine and sample all of the spoil bank plantings which could be located. During the course of field examinations, several areas were deleted from the sample because of restripping, grazing, or other factors which might unnaturally affect growth or survival. In all, 93 separate spoil areas comprising nearly 900 acres and over 1 million trees were included in the final field examination.

When one of the areas to be sampled had been located, general information was taken concerning topography, spoil material, and exposure. The area was then systematically sampled, with the intensity of sampling based on area, as follows: a 100 per cent sample was taken on areas of less than 0.5 acres; a 50 per cent sample was taken on areas of 0.6 to 1.0 acres; on areas of 1.1 to 3.0 acres, a 20 per cent sample was used; a 10 per cent sample was taken on areas over 3.0 acres. In many instances more than one species had been planted on a spoil bank area. Where this was the case, the area of **each** species planted was used as the basis for the intensity of the sample to be taken. All sampling lines were run across the topography of the spoil from the highwall, up over the reverse terrace, and down the outer slope. On each line, data were taken on the number of trees planted, number living, growth (current and total), crown spread, and spacing. An estimate was made of the natural vegetation present, both woody and herbaceous, and the prevailing aspect and slope per cent of the area were determined.

Results

Where cover and stabilization of strip-mined lands are of primary importance, good survival of tree plantings is of ultimate importance, for without good survival adequate distribution of seedlings

to provide that cover cannot be obtained. If a crop is desired, whether it is to be Christmas trees or a timber crop, good survival is necessary to insure a full stand on the area. For these reasons, survival has been used as the primary criterion for evaluating the over-all success of tree plantings on strip-mined areas sampled in this study. Growth, both total and current, has been used primarily in conjunction with survival and vigor in rating the performances of the individual species planted on spoils in the State.

ESTABLISHMENT OF TREE PLANTINGS ON A STATE-WIDE BASIS

There was much variation in the survival of the tree plantings sampled. For example, survival on one spoil area in Brooke County averaged only 20 per cent, while on another especially good spoil in Preston County the average survival was nearly 92 per cent. The average for all plantings throughout the State was 67.15 per cent. This figure can be considered quite good, especially since a wide range of spoil conditions is represented. The proportion of the total strip-mined area in each survival class is shown in Table 1.

For the purpose of rating the degree of success of the individual spoil bank plantings, stands with survivals of 60 per cent or better were considered to be successful, those with survivals of 40 to 59 per cent were rated as partially successful, and those with survivals less than 40 per cent were designated as failures. A summary of the evaluations obtained, using these criteria, is shown in Figure 1. This figure shows that successful stands of trees were established on nearly 75 per cent of the spoil area planted in the State. Failures resulted on only approximately 6 per cent of the planted area, while partially successful stands resulted on the remaining area.

Table 1. Survival, By Classes, of All Tree Plantings on Strip-Mined Areas In West Virginia

Per Cent Survival Class	Acreage in Class	Per Cent of Total Acreage in Class
0-9	0.0	0.0
10-19	6.2	0.7
20-29	17.7	2.0
30-39	27.1	3.0
40-49	77.1	8.6
50-59	110.3	12.2
60-69	209.1	23.2
70-79	278.7	31.0
80-89	147.5	16.4
90-100	26.1	2.9
Totals	899.8	100.0

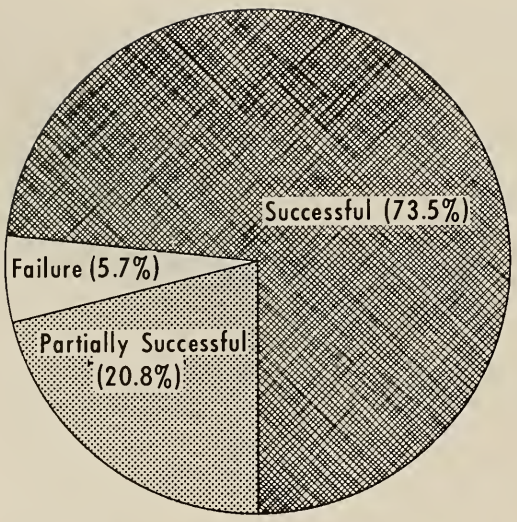

FIGURE 1. Success of establishment of all tree plantings on spoil bank areas in West Virginia. (Percentages are proportion of total spoil area of 899.8 acres planted with trees.)

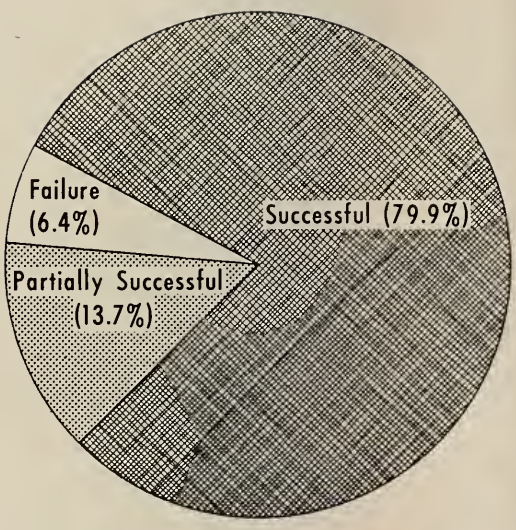

FIGURE 2. Success of establishment of black locust plantings on spoil bank areas in West Virginia. (Percentages are proportions of total spoil area of 338.1 acres planted with black locust.)

Consideration of the establishment of two main groups of species is also of interest. One of these groups includes all black locust stands on strip-mined areas in the State, and the other group includes all of the conifer plantings. As shown in Figure 2, stands of black locust were successful on nearly 80 per cent of the area planted, while 13.7 per cent were partially successful, and only 6.4 per cent were rated as failures. The corresponding values for the conifer plantings, as shown in Figure 3, were 67.8 per cent successful, 19.8 per cent partially successful, and 12.4 per cent were rated as failures. Comparison of the corresponding values for the two groups, black locust and conifers, indicates a comparatively small difference in their respective performances. However, it should be pointed out that black locust was often planted on more adverse sites than were the conifers. In nearly every instance where black locust and conifers were planted on similar sites, black locust exhibited the better performance. An excellent example of this is shown in Figure 5.

ESTABLISHMENT OF TREE PLANTINGS ON AN AREA BASIS

Although spoil and site conditions varied considerably throughout the State, conditions within limited areas were often quite similar. As shown in Figure 4, the strip-mined areas sampled in this study have been broken down into eight districts, each representing certain combinations of spoil and of site conditions. A summary of the

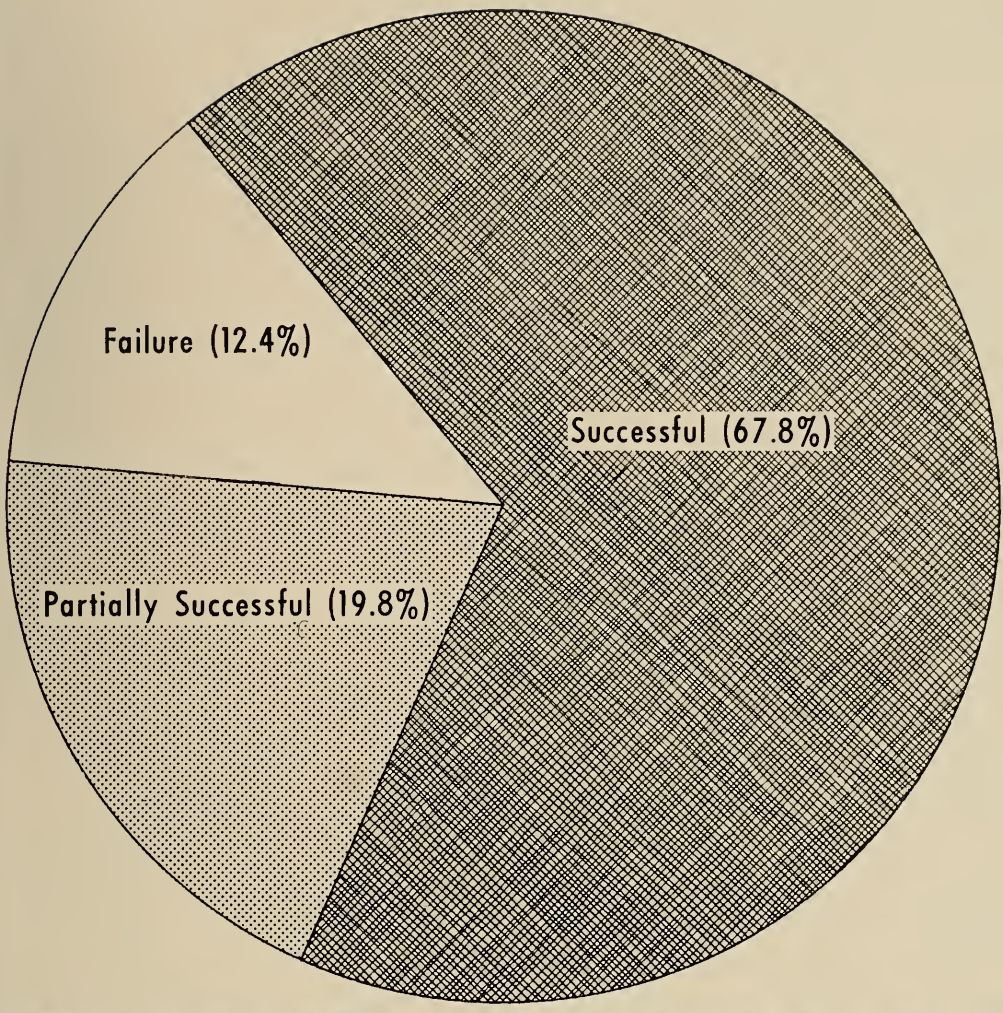

FIGURE 3. Success of establishment of conifer plantings on spoil bank areas in West Virginia. (Percentages are proportions of total spoil area of 550.7 acres planted with conifers.)

results of planting evaluations within each of these areas is shown in Table 2, and an explanation of the particular conditions in each area is presented in the paragraphs that follow.

District I. All plantings in this district were made on spoils created by strippings of the Pittsburgh coal seam at an elevation of approximately 1,100 feet. White pine, Scotch pine, and black locust were the principal species planted, with lesser amounts of shortleaf pine, Virginia pine, and European larch included. The relatively low average survival of 48.5 per cent can be attributed primarily to high acidity conditions associated with much of the overburden of the Pittsburgh coal seam in this area. Survivals on the 10 separate spoil areas in this district ranged from 20 to 80 per cent.

District II. As in District I, all spoil bank plantings in this district were made on Pittsburgh coal seam strippings. However, the

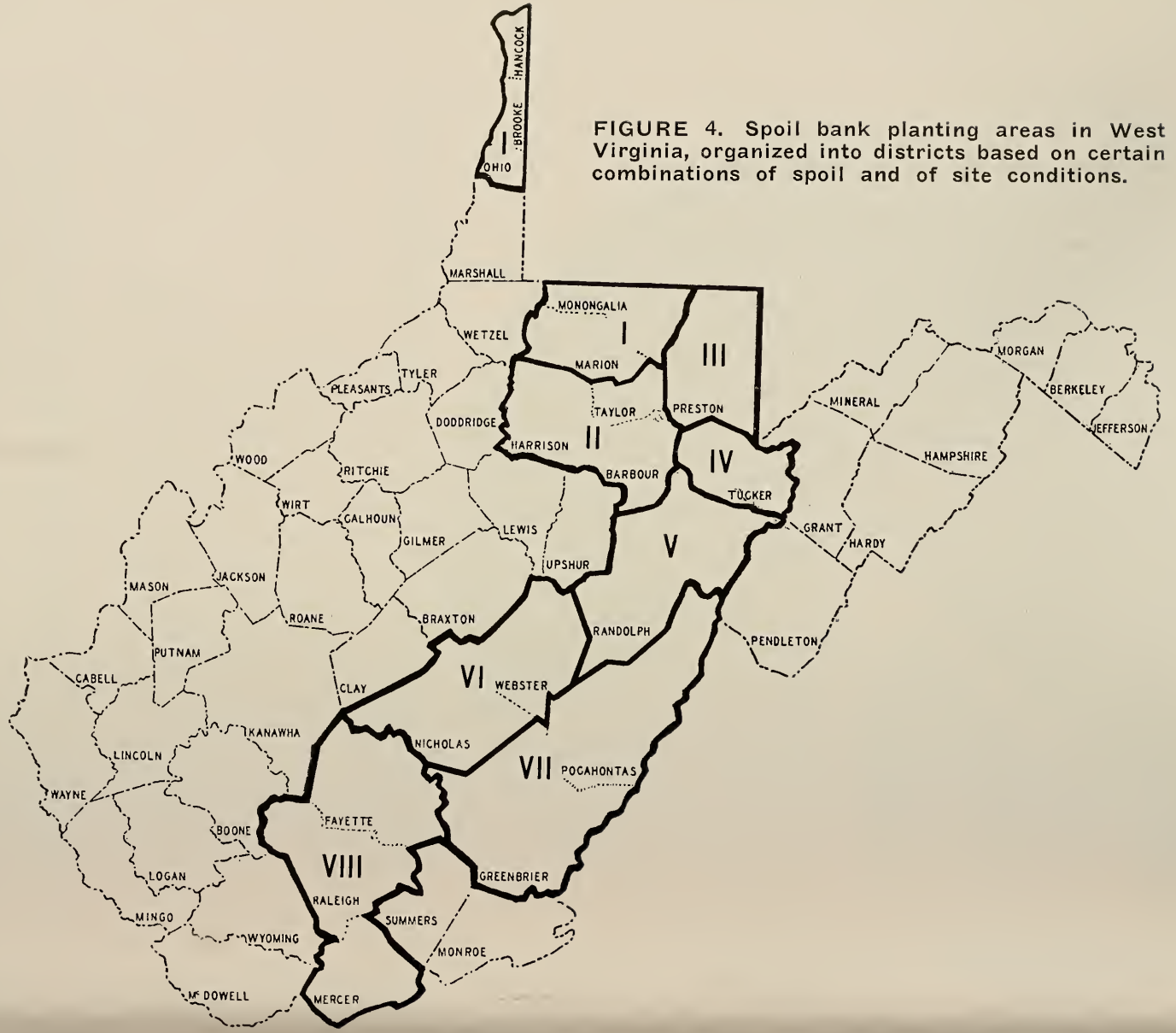

FIGURE 4. Spoil bank planting areas in West Virginia, organized into districts based on certain combinations of spoil and of site conditions.

Table 2. Summary of Evaluations of Spoil Bank Plantings in Eight Districts of West Virginia, With Each District Having Certain Combinations of Spoil or Site Conditions

District	Spoil Areas Planted	Acreage Planted	No. Trees Planted	Average % Survival
I	10	73.3	71,340	48.5
II	10	131.9	126,429	62.7
III	21	152.9	169,530	70.7
IV	7	72.1	95,970	66.3
V	8	37.4	43,693	61.0
VI	6	44.6	53,965	73.5
VII	8	140.9	284,010	57.9
VIII	25	246.7	301,075	80.1
Totals	95	899.8	1,146,012	67.15

overburden in this area is generally not so acid, and this accounts for the higher average survival of 62.7 per cent. Individual plantings in this district have survivals ranging from 53 to 73 per cent. Red pine, white pine, and black locust were the principal species planted, with some Scotch and shortleaf pines included.

District III. The 21 plantings in this Preston County district were made on Bakerstown and Upper Freeport coal seam spoils at elevations of 1,800 to 2,300 feet. Stands of black locust, Scotch pine, white pine, and red pine made up the bulk of the planting, with some European larch, Virginia pine, and Norway spruce included. Survivals varied from 38 to 92 per cent and averaged 70.7 per cent. Acidity problems were limited in most instances to plantings on Upper Freeport strippings.

District IV. Plantings in this Tucker County area were confined to Upper Freeport seam strippings at an elevation of 3,200 feet. Norway and red spruces, black locust, and red and Scotch pines were the species planted, with all doing fairly well, as may be evidenced by the 66.3 per cent average survival. Survivals on individual spoils ranged from 63 to 76 per cent. Acidity was not a serious problem, although spots of low pH were encountered on some spoils.

District V. Plantings in this district were made primarily on Kittanning seam strippings at an elevation of approximately 2,200 feet, with two plantings on Sewell seam strippings at 2,800 feet elevation. Survivals on Kittanning strippings ranged from 37 to 66 per cent, while the two plantings on Sewell strippings had survivals of 77.4 and 76.7 per cent. The lower survivals on Kittanning spoils can be attributed to areas of low pH. The average survival for the

district was 61.0 per cent. Stands of black locust, red pine, Virginia pine, Scotch pine, and white pine made up the bulk of the plantings.

District VI. All plantings in this district were made on Sewell seam spoils at elevations ranging from 2,700 to 3,000 feet. Black locust was the major species planted, with smaller numbers of white pine, Scotch pine, European larch and yellow-poplar included on the six planting sites. Acidity of spoil material was not a problem in this district, and this is reflected in the high average survival of 73.5 per cent. The range of survivals was from 68 to 80 per cent.

District VII. Plantings in this district were made on relatively well protected Sewell seam strippings at an elevation of 4,100 feet and on Hughes Ferry strippings at an elevation of 4,350 feet. Exposure to wind and severe winter weather conditions on the Hughes Ferry spoils greatly reduced the over-all survival in this district. For example, survivals on Sewell seam strippings varied from 56 to 75 per cent, while those on Hughes Ferry spoils ranged from 30 to 41 per cent. Average survival for the district was 57.9 per cent. Acidity was not a problem on either coal seam. Black locust, Norway and red spruce, and red and Scotch pines were the species planted, with all showing good survivals on the more protected sites.

District VIII. Plantings in this district were outstanding, as evidenced by the high average survival of 80.1 per cent. Plantings were made on strippings of two coal seams, Sewell at 2,000 feet elevation and Pocahontas No. 3 at 2,600 feet elevation. Survivals of the 25 separate plantings varied from 44 to 87 per cent. These figures are especially outstanding considering the large number of species (black locust, white, red, Scotch, and Virginia pines, European larch, yellow-poplar, and Norway spruce) and seven different age classes included in the plantings.

PERFORMANCES OF INDIVIDUAL SPECIES PLANTED ON SPOIL BANK AREAS

As shown in Table 3, 10 different species were planted on the spoil bank areas sampled in this study, with five of these species contributing 93 per cent of the total number of trees planted. Sixty-five separate stands of black locust, consisting of nearly 466,000 trees, made up over 40 per cent of the total planted, while extensively-planted stands of red, white, and Scotch pines each contributed from 11.9 to 16.3 per cent of the State-wide total. Norway spruce, although not so widely planted (only 18 stands), contributed 11.5 per cent of

Table 3. Summary of Evaluations of Performances of Tree Species Planted on Strip-Mined Areas in West Virginia

Species	No. of Separate Plantings	Area Planted		Trees Planted		Average Survival
		Acres	Per Cent of Total	Number	Per Cent of Total	
Black Locust	65	338.1	37.6	465,833	40.7	68.7
Red Pine	45	148.9	16.5	186,752	16.3	70.6
White Pine	51	134.7	15.0	148,695	13.0	68.8
Scotch Pine	47	121.0	13.5	136,715	11.9	65.8
Norway Spruce	18	92.2	10.2	132,090	11.5	59.1
Red Spruce	3	22.2	2.5	26,880	2.4	63.2
Virginia Pine	10	15.9	1.8	17,413	1.5	48.7
Yellow-Poplar	5	11.0	1.2	13,010	1.1	80.3
European Larch	7	9.0	1.0	11,866	1.0	66.9
Shortleaf Pine	5	6.8	0.7	6,758	0.6	51.1
Totals	256	899.8	100.0	1,146,012	100.0	67.15

the total. The remaining five species were rather limited in both number of stands (from 3 plantings of red spruce to 10 plantings of Virginia pine) and in total number of trees planted (from approximately 6,800 shortleaf pine to nearly 27,000 red spruce).

Average survivals of the different species planted were generally quite good, ranging from a low of 48.7 per cent for Virginia pine to 80.3 per cent for yellow-poplar. However, survival figures alone cannot be used as the criteria for rating the performances of the individual species. This is quite obvious from the figures presented above for Virginia pine and yellow-poplar, because based on survival figures alone it would be concluded that Virginia pine is the poorest species for spoil bank planting, while yellow-poplar is the best. From other experience with these species it is known that this is not true. Thus, it is obvious that factors other than survival must also be considered.

In the paragraphs that follow, each of the species listed in Table 3 is discussed in relation to its survival, growth, and suitability for planting on strip-mined areas in West Virginia.

Black Locust. From the standpoint of survival, growth, and adaptability, black locust was by far the outstanding species planted on spoil bank areas in West Virginia. Although the over-all survival of 68.7 per cent for black locust was approximately the same as that for several other species, none of these others was planted on as great a variety of sites, especially adverse sites, as was locust. For example, on many spoil areas conifers were planted on the better portions of the spoil, while locust was planted on the steep outerslopes. In plantings on comparable areas, locust showed better sur-

FIGURE 5. Barbour County planting illustrates superior growth and survival of black locust when planted on strip-mined areas. Background of this spoil was planted with black locust, foreground with red pine. After four growing seasons, the black locust averaged 11 feet in height, with 90 per cent survival. Red pine averaged 12 inches in height, with 40 per cent survival.

vival and growth in nearly every instance. An excellent example of this is shown in Figure 5.

Black locust displayed several characteristics that made it ideal for providing cover and stabilization of spoil bank areas. It produced seed at an early age and, as shown in Figure 6, deposited large amounts of litter. Its rapid juvenile growth and spreading crown habit gave crown closure at an early age, with many stands planted on a 7 by 7-foot spacing having closed canopies after four growing seasons. In addition, locust, being a legume, can add nitrogen to the spoil material. This is especially important since nitrogen is one primary element usually deficient in newly-formed spoil material (Chapman 1947). The shade, organic matter and nitrogen provided by locust greatly improved spoil conditions, and in most cases the ground under locust stands was covered with a profuse growth of herbs and grasses (Figure 7). These same conditions also favored the establishment of naturally-seeded tree species, such as birches, maples, sycamore, poplars, yellow-poplar, and others.

Because of its multiple-stemmed growth habit and because of insect damage to the trees by the locust borer **(Megacyllene robiniae)**, very little in the way of a usable product could be expected from most of the stands of black locust planted on strip-mined areas in West Virginia.

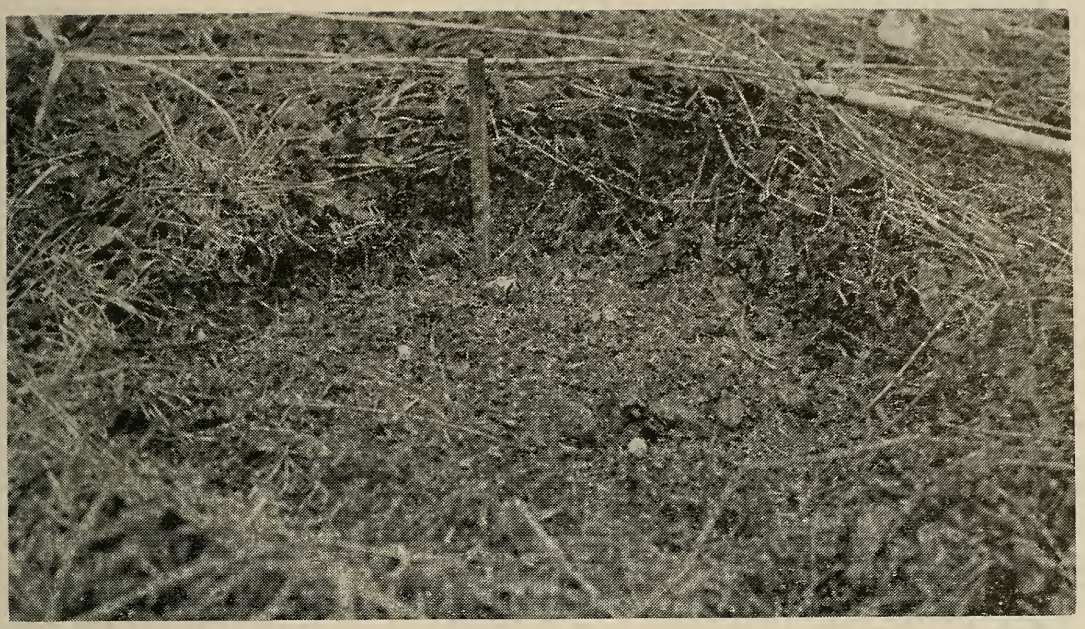

FIGURE 6. Litter accumulation under black locust stand in Fayette County. Nearly 4 inches of litter has accumulated under this seven-year-old stand. Compare with bare surface of area under red pine in Figure 9.

Scotch Pine. The individual plantings of Scotch pine (Figure 8), showing an average survival of 65.8 per cent, were well distributed on a variety of spoil bank sites throughout the State. Survivals on individual areas varied from 21 to 97 per cent, with low survivals occurring primarily on spoil material having a pH below 4.0. The average survival for all plantings on spoils with pH above 4.0 was 80.5 per cent. Growth of Scotch pine was good, averaging approximately 3 feet at five years of age and over 6.5 feet at eight years. Based on survival, growth, and adaptability, Scotch pine would be rated as the **best** of the conifers planted on spoil bank areas in West Virginia.

Red Pine. As with Scotch pine, the 47 stands of red pine sampled in this study were well distributed, with some planting of this species in all but Region I (see Figure 4). Performance of red pine was nearly as good as that of Scotch pine, with an average survival of 70.6 per cent for all plantings and 71.6 per cent for areas having a pH above 4.0. Very little red pine was planted on spoils of low pH, which accounts for the small increase in survival when areas of low pH are deleted from the sample. Heights of red pine averaged nearly 2.5 feet at five years and 5.5 feet at eight years. Based on survival, growth, and adaptability of the stands evaluated in this study, red pine would be rated as the **second** best conifer planted on spoil bank areas in West Virginia. An excellent young stand of red pine is shown in Figure 9.

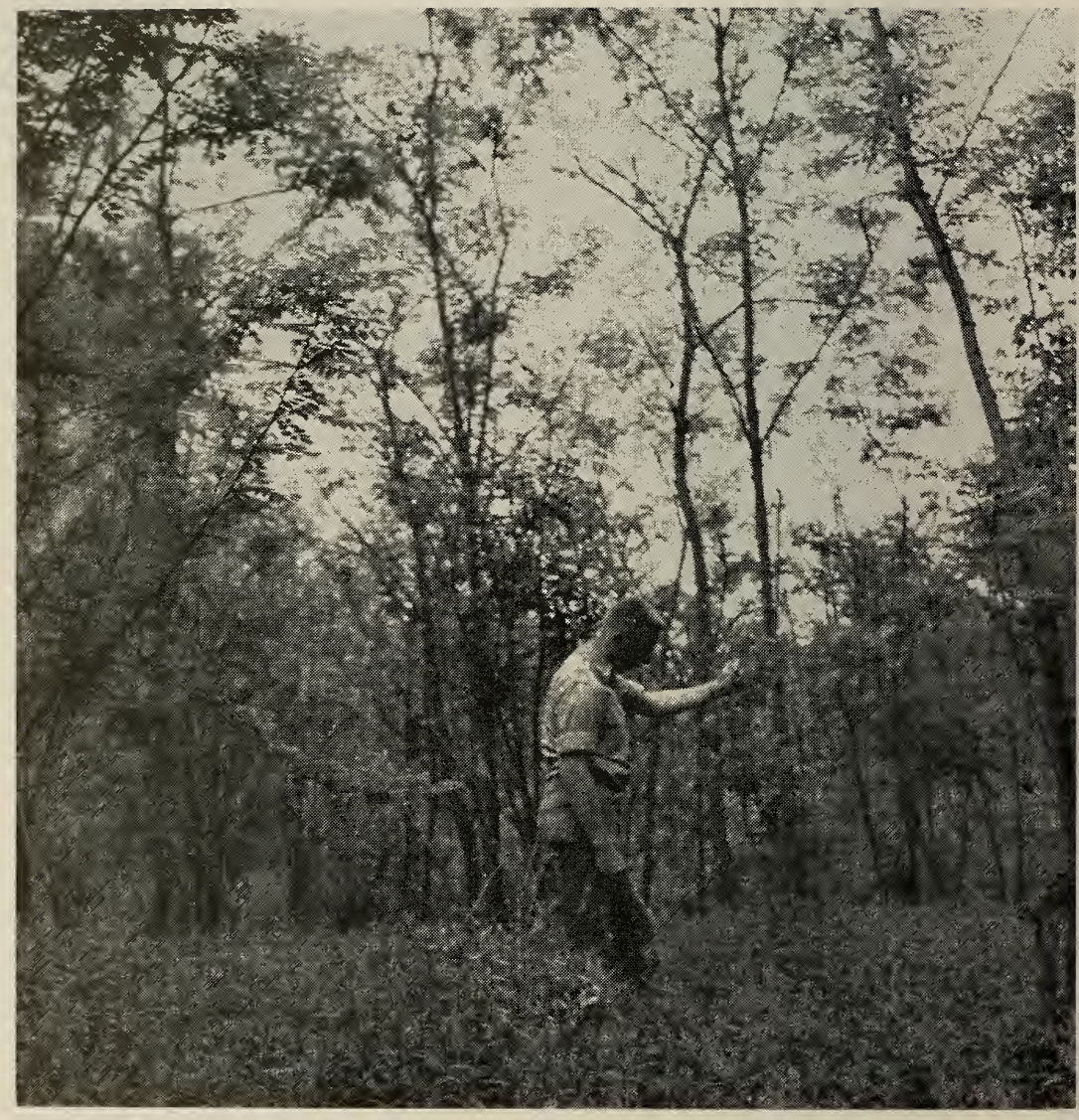

FIGURE 7. Improved spoil conditions under black locust stands are favorable for establishment of herbaceous plants, like the goldenrod under this stand in Raleigh County.

Despite its good performance on these study areas, caution should be exercised in planting red pine, which is native to the northern United States and southern Canada. Stands of this species planted in warmer areas often grow well for the first 10 to 15 years. After this, growth often declines markedly, and in some cases trees begin to die and stands to break-up after 25 to 30 years. In addition, plantings of red pine in warmer areas are subject to attack by the European pine shoot moth (**Rhyacionia buoliana** [Schiff.]). This insect attacks and kills the terminal and lateral buds of the trees. This causes stunted, bushy, and crooked stems. Therefore, plantings of red pine in the State should not be made in warmer areas. In most of West Vir-

FIGURE 8. Early growth and establishment make Scotch pine ideal for planting on spoil bank areas. This Tucker County stand averaged nearly 9 feet tall with 80 per cent survival after eight growing seasons.

ginia, red pine at elevations above 2,200 to 2,400 feet should be reasonably safe from the serious growth decline and attack by the European pine shoot moth.

White Pine. Survival of white pine (Figure 10) was good, averaging 68.8 per cent for all 51 plantings throughout the State and nearly 78 per cent for plantings on strip-mined areas having spoil material with a pH above 4.0. Survival of individual plantings ranged from 12 to 93 per cent, with most of the low survivals occurring on areas of

FIGURE 9. Stands of red pine, like this Fayette County planting, survived and grew well on spoil bank areas in West Virginia. After six growing seasons, these trees averaged 4 feet in height; survival was 80 per cent.

high acidity. Early growth of white pine was not as good as that of red or Scotch pine, with trees averaging about 2 feet in height after five growing seasons. However, by the time trees were eight years old, the average height was 5.5 feet (the same as for red pine) and by ten years of age the total height of white pine equalled or exceeded that of red and Scotch pines. Because of slow growth during the first few years after planting, early evaluations of white pine plantings may be misleading. Based on survival, growth and adaptability, white pine would be rated as the **third** best of the conifers planted in large quantities on spoils in West Virginia. However, if a sawlog crop is the desired objective of planting, it is possible that white pine would be the best species that could be planted.

Norway Spruce and Red Spruce. Nearly all of the Norway and red spruce planted on strip-mined areas evaluated in this study were on spoils in either Region IV at an elevation of 3,200 feet or in Region VII at elevations over 4,000 feet (see Figure 4). One of these stands is shown in Figure 11. The average survival for these two

FIGURE 10. Growth of white pine planted on this Preston County spoil bank was excellent. Trees averaged 9 feet in height after ten growing seasons. Note bushy appearance of lower portions of the trees—the results of slow growth during the first few years after planting.

species was approximately 60 per cent, and survivals of plantings on individual areas ranged from 12 to 84 per cent. The lowest survivals occurred on extremely exposed sites at an elevation of 4,350 feet. Such an area is shown in Figure 12. On protected areas at nearly the same elevation, survival was good. Growth of the spruces was very slow for the first six or seven years after planting, and seven-year-old trees averaged only 1.5 feet in height. After this, growth was normally good, with 10-year-old stands averaging over 4 feet in height.

Virginia Pine. The low average survival of 48.7 per cent for the Virginia pine (Figure 13) sampled in this study can be attributed to

FIGURE 11. Growth of the spruces (Norway and red) was quite slow for the first six or seven years following planting. After this, growth was usually good. This stand of Norway spruce in Tucker County had 65 per cent survival, and a height of 4 feet after ten growing seasons.

high acidity. Five of the ten plantings, making up over half of the total number of trees planted, were located on spoils having at least some spots of low pH. Plantings of Virginia pine on spoils in Illinois have done quite well (Boyce and Nebbe 1959). Tryon **et al.** (1960)

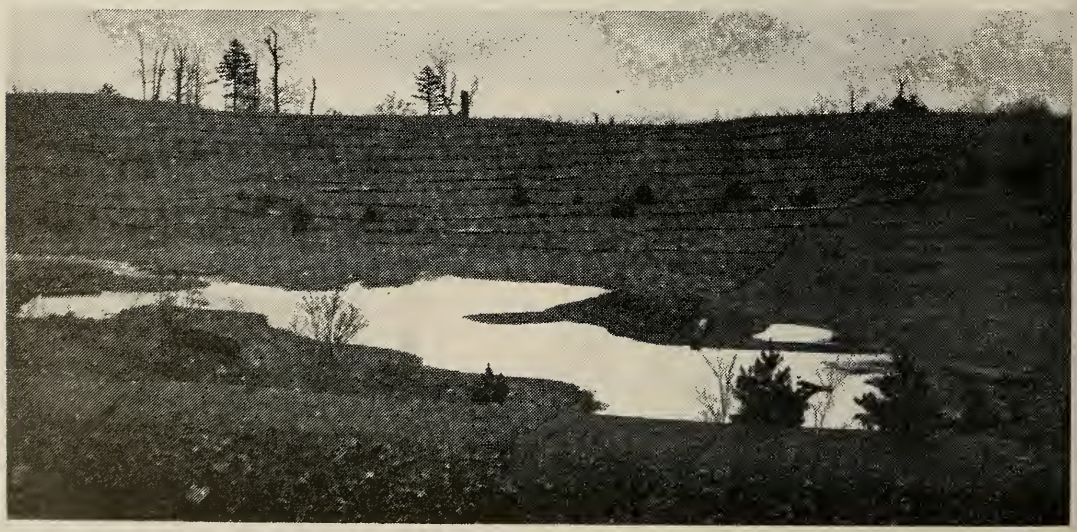

FIGURE 12. Norway spruce planted on Pocahontas County spoil, elevation 4,350 feet, failed because of extreme exposure to wind and severe winter weather. Note logs placed along spoil surface in an effort to break effects of wind.

FIGURE 13. Growth and adaptability of Virginia pine make it ideal for planting on strip-mined areas. This Randolph County stand averaged nearly 6 feet in height after six growing seasons.

recommend Virginia pine for planting on poorer sites in West Virginia. Growth of Virginia pine was exceptionally good, amounting to nearly 5 feet in height after five growing seasons. Based on the growth of this species and experiences with it in other states, Virginia pine would probably be rated as one of the better species for planting on strip-mined areas in West Virginia.

European Larch. Although survival of the seven plantings of European larch sampled in this study was good (66.9 per cent), the over-all performance of the species was very poor. Growth and form were extremely variable, with a large proportion of the trees being prostrate with no dominant leaders. Figure 14 shows a European larch stand having trees ranging from prostrate form to straight, well-formed trees. Essentially the same results were obtained with this species by Hart and Byrnes (1960) in Pennsylvania. Based on the performance of European larch on West Virginia and Pennsylvania spoils, planting of this species cannot generally be recommended.

FIGURE 14. The stem form of European larch planted on spoil bank areas in West Virginia is extremely variable. Many trees are prostrate and have no dominant leader.

Yellow-Poplar. The plantings of yellow-poplar sampled in this study, showing an average survival of 80.3 per cent, are probably not indicative of the performance of the species under a variety of spoil conditions. Experience with yellow-poplar in Illinois (Boyce and Nebbe 1959), Kentucky (Boyce and Merz 1959), and Ohio (Finn 1958) indicate that it will not do well on most strip-mined areas. The good performance of all five of the plantings sampled in this study can be attributed to the fact that they were located on the better portions of spoils, where moisture and other conditions were most favorable. Growth, in addition to survival, was excellent, with five-year-old trees averaging over 6 feet in height. One particularly good six-year-old stand averaged 11 feet in height, with individual trees up to 15 feet tall (Figure 15). Although growth and survival such as this cannot be expected on most spoil areas, results do indicate the possibility that yellow-poplar might do well on the better portions of many strip-mined sites.

Shortleaf Pine. The five stands of shortleaf pine sampled in this study were insufficient to afford an accurate estimate of the performance of the species. Two of the plantings made at lower elevations did quite well, while one planting at a higher elevation in the northern part of the State was beginning to die 10 years after planting. Similar results were obtained with shortleaf pine planted on spoils

FIGURE 15. This stand of yellow-poplar in Fayette County was growing exceptionally well, with an average height of 10 feet after seven growing seasons. Individual trees ranged up to 15 feet tall and survival averaged 90 per cent.

in Illinois (Boyce and Nebbe 1959). Tryon, et al. (1960) recommend shortleaf pine for planting on eroded and dry sites at elevations of 1,000 feet or less in West Virginia.

SITE FACTORS AFFECTING THE ESTABLISHMENT AND GROWTH OF PLANTINGS ON SPOIL BANK AREAS

Many factors affect the establishment and growth of trees planted on strip-mined areas throughout the State. Of the factors included in this study, acidity of spoil material, precipitation, per cent slope, grading, and elevation showed a relationship to the growth and survival of the trees planted on spoils.

Relationship Between Survival of Plantings and Precipitation During the First Growing Season After Planting

In studying the effects of precipitation on survival of tree plantings on spoil banks, areas of low pH, extreme exposure (such as plantings on Hughes Ferry seam strippings in Region VII), and excessive erosion were deleted from the sample. Evaluations were then made

of the relationship between per cent survival and precipitation during various periods of the first growing season. The results of these evaluations are presented in Table 4. As may be seen from this table, black locust and the coniferous species planted on spoils showed definite correlations between survival and precipitation during certain periods, with the survival of conifers being more closely correlated with precipitation than was the survival of black locust. (F values for conifers were significant at the 1 per cent level, while those for black locust were significant at the 5 per cent level.) This indicates that black locust seedlings are more hardy than are the conifers and are not as sensitive to fluctuations in precipitation.

Survival of black locust was most closely correlated with precipitation during the full growing season period of April to September, with the F value declining slightly when September precipitation was deleted. (F values for the April to September and April to August periods were 6.59 and 6.33, respectively.) Survival of the conifers, on the other hand, was definitely most closely correlated with April to August precipitation, and significance fell off decidedly when September precipitation was included. (F values were 21.13 and 15.97, respectively, for these two periods.) This difference in the periods of greatest relationship for the conifers and black locust can probably be attributed to the fact that the conifers have completed growth and hardened-off by the end of August, while black locust continues to grow until hit by frost in the fall. Figure 16 shows the relationship between survival of plantings and precipitation during the full growing season.

Table 4. Relationship (F Values) Between Survival of Tree Plantings on Spoil Bank Areas in West Virginia and Precipitation During Selected Periods

Precipitation Periods	F Value from Analysis of Variance for	
	Black Locust	Conifers
April	No significance	No significance
May	5.20*	15.11**
June	No significance	No significance
April—May	5.98*	16.81**
April—June	No significance	No significance
April—July	4.52*	16.56**
April—August	6.33*	21.13**
April—September	6.59*	15.97**
May—June	No significance	No significance

*F values as here presented are significant at the 5 per cent level.
**F values as here presented are significant at the 1 per cent level.

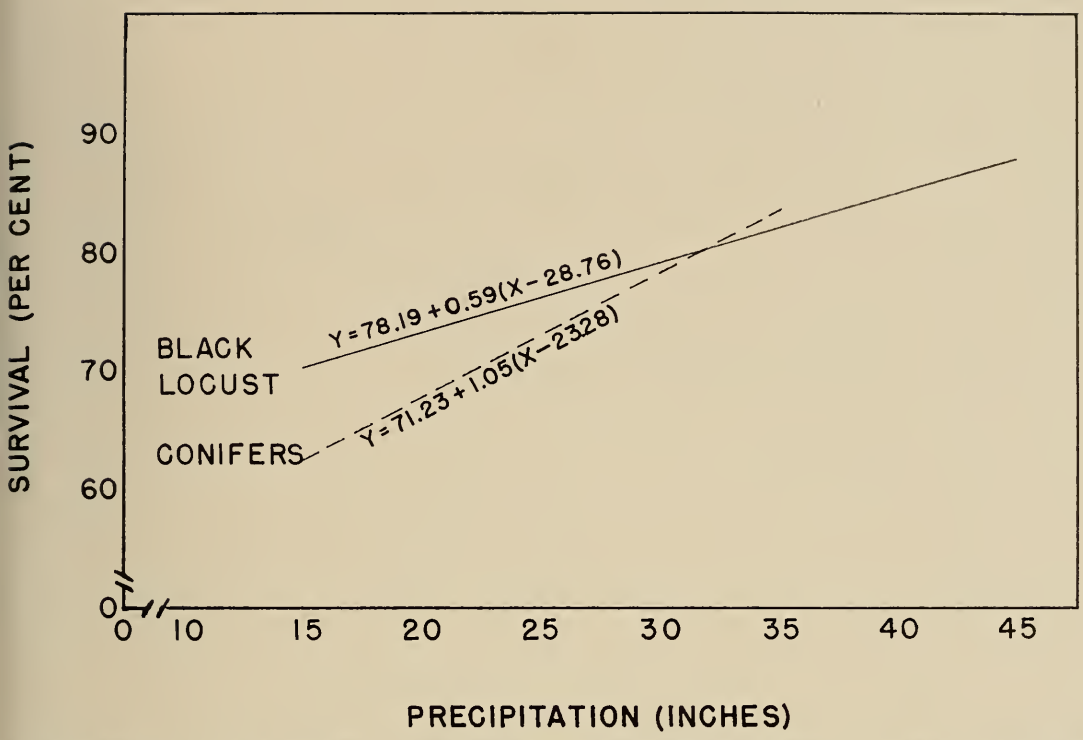

FIGURE 16. Relationship (regression) between survival of tree plantings on spoil bank areas and precipitation during the April to September period for black locust and the April to August period for conifers.

Survival of both the conifers and black locust was also correlated with precipitation for the April to May period (Figure 17), although this correlation was not so high as that for the April to August period for conifers or April to September period for black locust. F values for the April to May period were 16.81 for conifers and 5.98 for black locust. The correlation between survival and precipitation during this period can be explained by the fact that seedlings are particularly sensitive to fluctuations in soil moisture during the month of planting (April) and the month after planting (May).

Correlations were also significant between survival and precipitation for the periods April to July and for May, although these correlations were not so good as those for the previously mentioned periods. No relationship was noted between survival and precipitation during the April, June, April to June, and May to June periods.

Effects of Steepness of Slope on Survival and Growth of Black Locust

Only stands of black locust which had been established on ungraded spoil areas were used in studying the effects of steepness of slope on the growth and survival of strip-mine plantings. These stands included over 150,000 black locust seedlings planted on sites

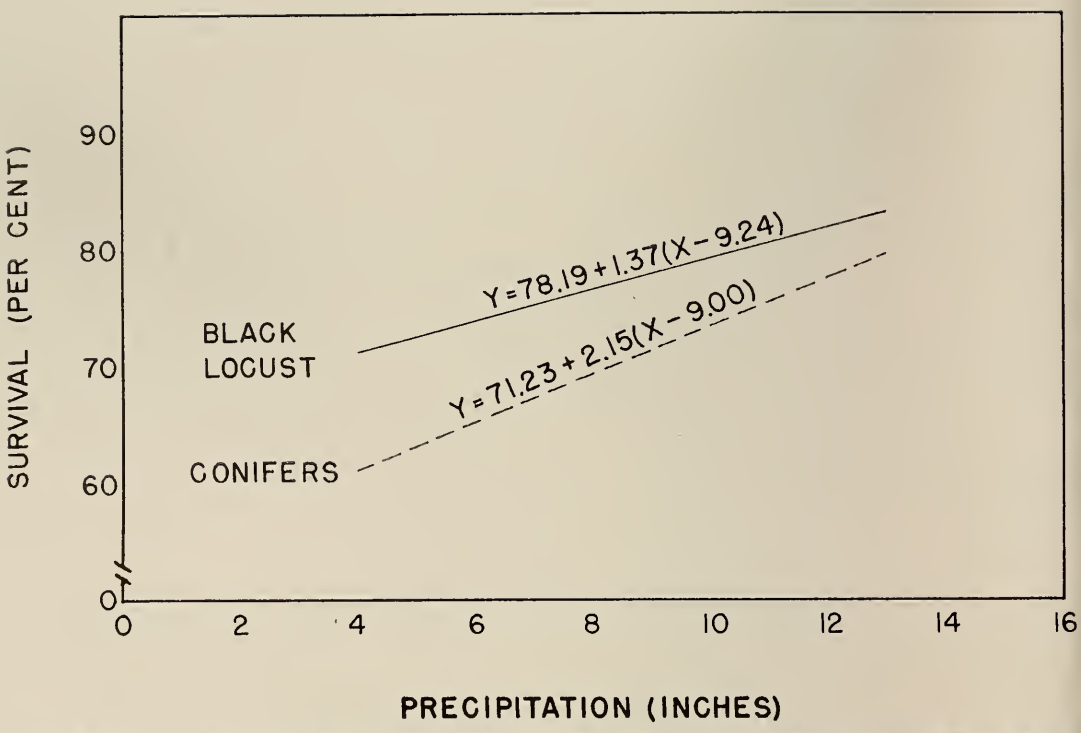

FIGURE 17. Relationship (regression) of survival of tree plantings on spoil bank areas to precipitation during the seedling establishment period of April and May.

ranging in slope from 25 to 85 per cent. The conifers and yellow-poplar were not used because insufficient numbers of these species were planted on the outer slopes of spoils to provide an accurate estimate of their performances on the steeper areas.

A definite correlation between slope and the survival of black locust was found on the sites studied. As may be seen in Figure 18, survival of black locust declined in direct relationship to increases in slope. The maximum survival of 84 per cent was measured on 25 per cent slopes, while the minimum survival of approximately 60 per cent was encountered on slopes of 85 per cent. This regression, showing a decline in survival of 3.4 per cent for each 10 per cent increase in slope, was significant at the 1 per cent level.

Growth of black locust was also found to be correlated with slope. As shown in Figure 19, average annual growth of black locust was quite uniform on slopes of 25 to approximately 40 per cent. Above 40 per cent, growth declined steadily in direct relationship to increases in slope per cent.

Effects of Elevation on Growth and Survival of Plantings

Tree plantings on strip-mined areas in West Virginia were made at elevations ranging from approximately 1,100 feet to nearly 4,350

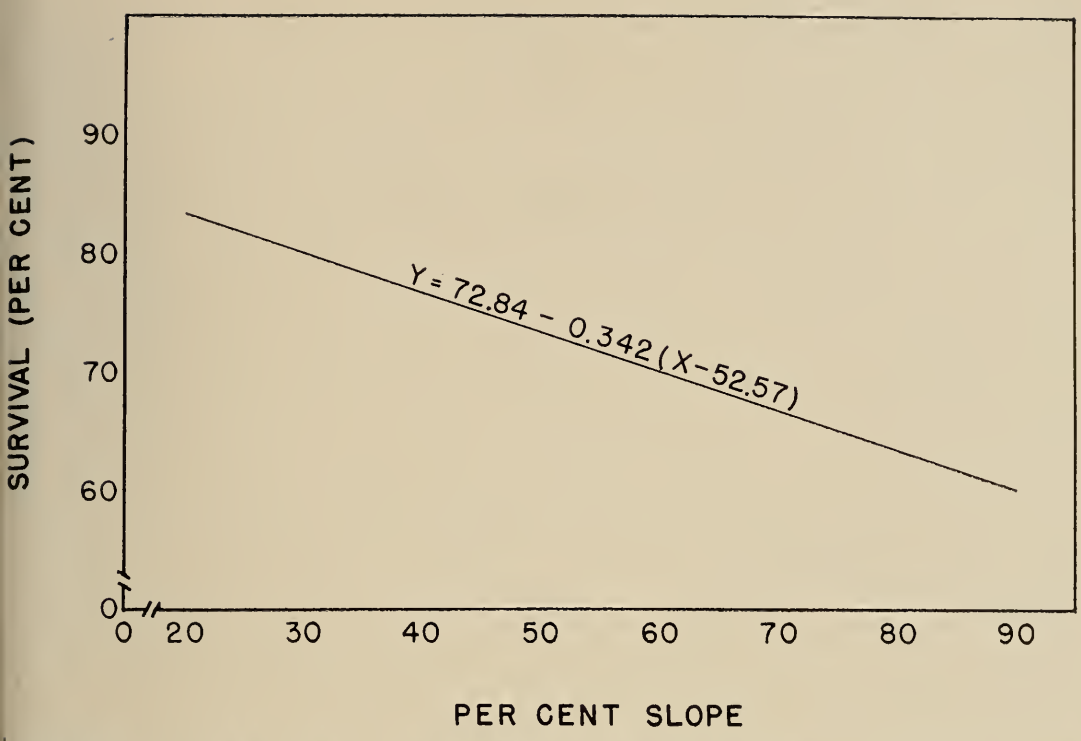

FIGURE 18. Relationship (regression) of survival of black locust plantings on spoil bank areas to slope per cent.

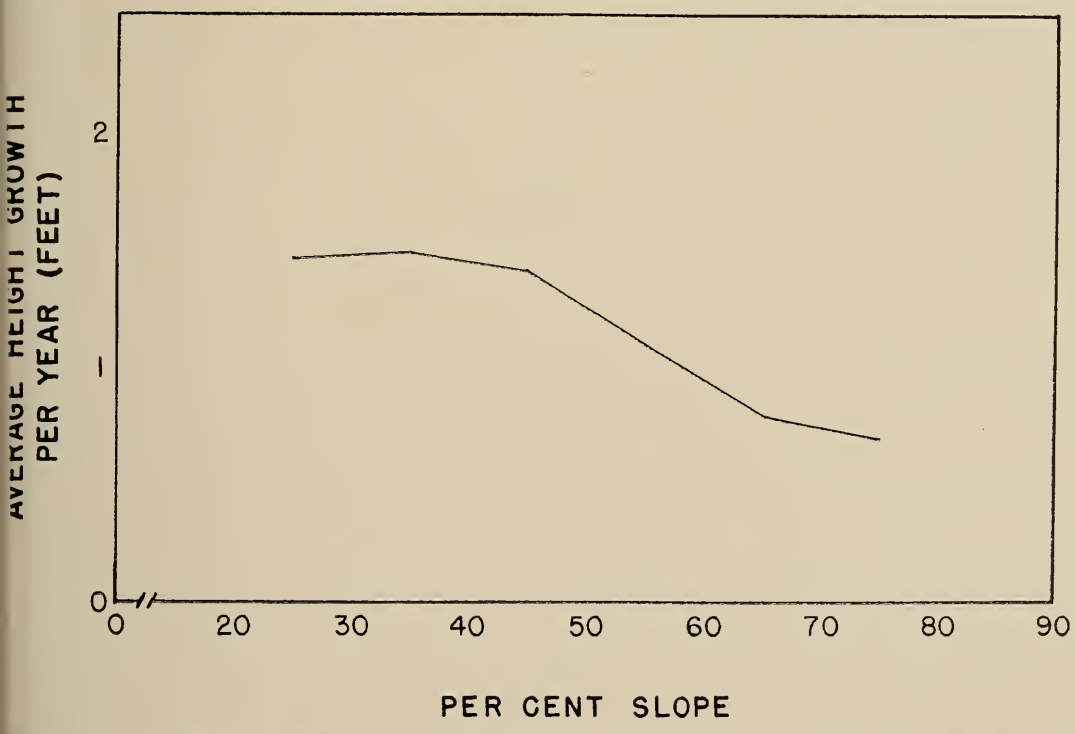

FIGURE 19. Relationship between growth of black locust and slope of spoil bank planting site.

feet. The effects of changes in elevation on the growth and survival of these plantings were very pronounced. In studying the effects of elevation on growth and survival, all areas of low pH, extreme exposure, and excessive erosion were deleted from the sample. Also, in studying the effects of changes in elevation on growth and survival of conifers, only stands of red and Scotch pine were used in making comparisons. Other conifers were not used because they had not been planted throughout the full range of elevations encountered in this study. (For example, white pine was not planted above 2,800 feet, while the spruces were planted principally above 3,000 feet elevation.)

Black locust in particular showed a decided reaction to changes in elevation. As shown in Figure 20, survival of black locust averaged approximately 80 per cent on spoils at elevations of 1,100 to 2,200 feet. Above 2,200 feet, survival decreased steadily, at a nearly constant rate, as elevation increased, until plantings at 4,350 feet had an average survival of less than 65 per cent.

The effects of changes in elevation on the growth of black locust were even more pronounced, with total height declining in direct relationship to increases in elevation. As shown in Figure 21, the average annual growth of locust was greatest at 1,100 feet elevation

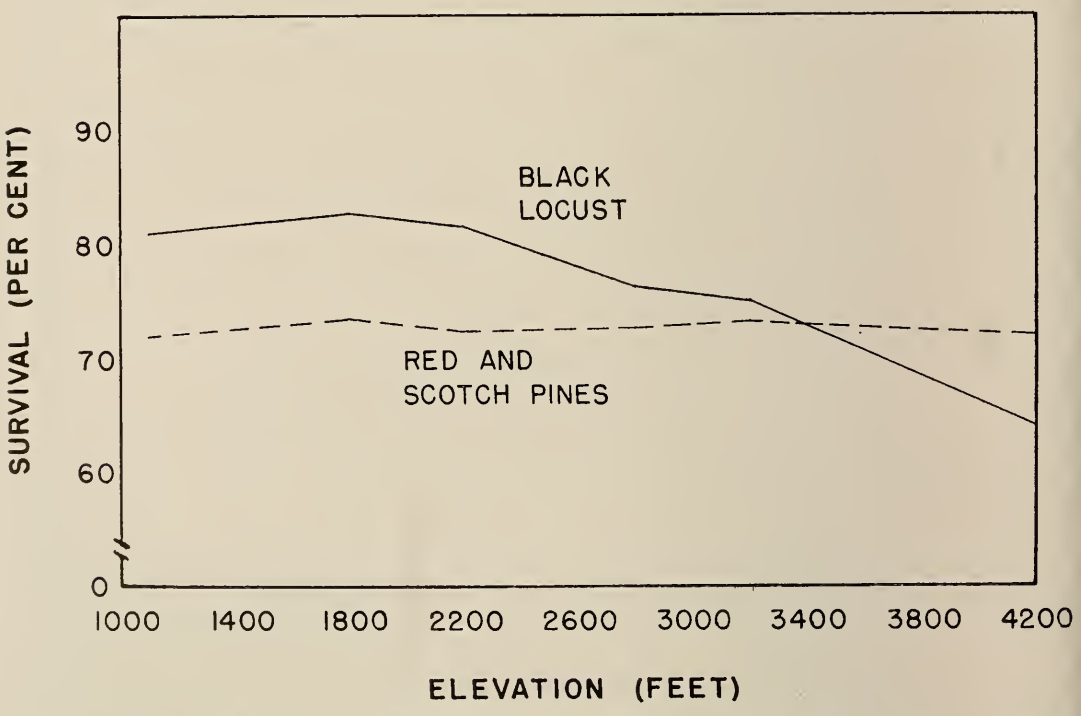

FIGURE 20. Relation of survival of tree plantings on spoil bank areas to elevation of planting site.

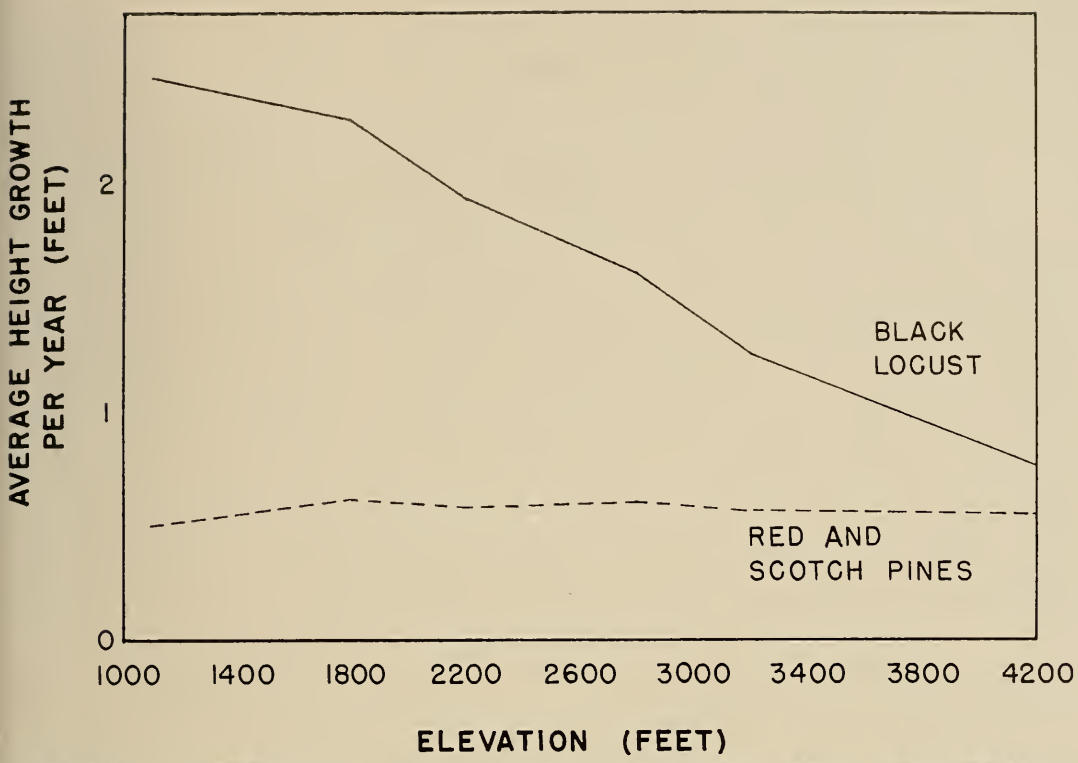

FIGURE 21. Relation of growth of tree plantings on spoil bank areas to elevation of planting site.

and least on plantings at 4,350 feet elevation. Between these two extremes, growth declined at a nearly constant rate as elevation increased. This decrease in the growth of black locust as elevation increases can probably be explained by the fact that black locust normally continues height growth until hit by frost in the late summer or fall. Since the length of the frost-free growing season becomes shorter as elevation increases, the time available for growth of locust decreases as elevation increases, and total growth is thereby reduced.

Unlike black locust, the growth or survival of red and Scotch pines was not affected by increases in elevation, and growth and survival at the lower elevations of 1,100 to 1,600 feet was nearly the same as that at the highest elevation, 4,350 feet. This uniform growth and survival at all elevations can probably be attributed to the fact that these species complete their growth and harden-off well in advance of any killing frosts at even the higher elevations.

Effects of Grading on Growth and Survival of Spoil Bank Plantings

In studying the effects of grading, and its resulting compaction, on the growth and survival of trees planted on strip-mined areas, comparisons were made using only those stands established on both

graded and ungraded portions of individaul spoils. This procedure was used in order to minimize any differences in spoil material and other site factors which might be encountered from one area to another. Only 15 such stands were sampled in this study, and the relative growth and survivals of these stands are presented in Table 5.

As may be seen in this table, grading generally resulted in reduced growth of trees planted on strip-mined areas. On the other hand, survival did not seem to be affected by compaction, and approximately equal survivals were obtained on graded and ungraded portions of spoil areas. These results are quite similar to those obtained on many areas in the Central States (Limstrom 1960). Experiments there indicate that the slower growth on graded banks is associated with reductions in pore space, water-holding capacity, and infiltration and percolation rates in the graded spoil material. These factors were found to be most pronounced on heavier soils.

Effects of Acidity of Spoil Material on Survival of Plantings

Because of the sampling procedure used in this study, it was impossible to associate the survival of plantings with the exact pH of the spoil material at a particular spot or area. Therefore, for the purpose of making comparisons, the sampled spoil areas were segregated into three groups. One of these groups, classified as the toxic, consisted of all spoils having over 50 per cent of their area with pH less than 4.0. The intermediate group contained all spoils with 50 to 75 per cent of their area having pH above 4.0, while those areas

Table 5. Effects of Grading and Compaction on Growth and Survival of Tree Plantings on Spoil Bank Areas in West Virginia

Location of Planting	Species Planted	Age at Time of Sampling	Survival (%)		Average Ht. (Inches)	
			Graded	Ungraded	Graded	Ungraded
Randolph	Black Locust	4	81.3	84.1	40	49
Randolph	Black Locust	12	70.0	79.3	217	261
Brooke	Black Locust	5	81.0	84.0	132	150
Brooke	White Pine	4	75.0	79.9	19	28
Raleigh	Yellow-Poplar	7	90.3	87.2	79	120
Pocahontas	Black Locust	10	88.3	77.6	108	126
Pocahontas	Black Locust	3	46.4	49.1	29	35
Nicholas	Black Locust	8	83.8	75.2	88	110
Barbour	Red Pine	4	73.0	71.0	15	22
Barbour	White Pine	4	61.2	60.6	13	20
Barbour	Black Locust	4	73.0	77.0	120	137
Barbour	Black Locust	4	70.1	66.2	98	116
Preston	Scotch Pine	4	77.3	67.8	30	43
Preston	White Pine	4	86.8	78.9	16	19
Preston	Black Locust	4	80.9	77.9	72	90

classified as nontoxic had less than 25 per cent of their area with pH less than 4.0. A summary of evaluations, using these criteria, is shown in Table 6. All areas of excessive erosion or extreme exposure were deleted from the sample in making these comparisons.

As may be seen from Table 6, survival of plantings was directly related to the proportion of their total area which was composed of toxic spoil material (pH less than 4.0). On those areas with over half their spoil material with pH below 4.0, survival averaged less than 35 per cent, while on areas with one-fourth to one-half their area in toxic material the average survival was nearly 60 per cent. On those areas classed as nontoxic, survival averaged better than 75 per cent.

Fortunately only a relatively small proportion of the total spoil area sampled fell into the toxic class. The 8.2 per cent of the total area in the toxic class agrees very closely with earlier findings of Brown and Tryon (1960) and Porter, **et al.** (1951).

Table 6. Distribution of Sampled Spoil Bank Area By Acidity Class

Acidity Class	No. Trees Planted	Average Survival	Acreage Planted	Per Cent of Total Acreage
		Per Cent		
Nontoxic	774,449	75.5	637.9	70.9
Intermediate	134,235	59.6	111.6	12.4
Toxic	73,058	34.5	73.9	8.2
Sub-totals	981,742	——	823.4	91.5
Area Deleted from Sample	164,270	——	76.4	8.5
Totals	1,146,012	——	899.8	100.0

Poor Planting as a Cause of Poor Growth and Mortality in Plantings

In making the evaluations in this study, one major factor contributing to reduced vigor and mortality of plantings became very obvious. This factor was poor planting. Although no systematic sampling to study this problem was made, examination of individual seedlings on many spoils disclosed cases of "shovel root," planting too shallow, planting too deep, and other related problems. As pointed out by Brown and Carvell (1961), all of these things can result in reduced vigor and growth and even mortality of seedlings. These problems are particularly acute on heavier soils (as are many of the strip-mined sites in West Virginia) and can best be eliminated through the careful execution of the planting operation. Where spoil material is heavy or stock is large, it is much better to use mattocks rather than planting bars.

Summary

Surface mining of coal has directly affected nearly 70,000 acres of land in 36 of West Virginia's 55 counties. Revegetation offers the most practical means of stabilizing these areas and returning them to a productive condition.

A survey of tree plantings established on spoil areas throughout the State revealed the following:

1. Successful stands of trees were established on nearly 75 per cent of the spoil bank area planted in the State, while partially successful stands resulted on approximately 20 per cent of the area planted. Stands were rated as failures on only 6 per cent of the total area planted.

2. Although spoil and site conditions varied considerably throughout West Virginia, conditions within limited areas were often quite similar. For this reason, the spoil bank planting sites in the State were broken down into eight districts, each having certain combinations of spoil or site conditions. Results of evaluations in each of these districts are presented in Table 2.

3. Ten different species were planted on the areas evaluated in this study. Of these, black locust stands made up over 40 per cent of the total number of trees planted, while stands of red, white and Scotch pines, and Norway spruce contributed from 11.5 to 16.3 per cent of the total number of trees planted. Lesser numbers of red spruce, Virginia and shortleaf pines, European larch, and yellow-poplar were also included in the plantings.

4. Survivals of the different species planted were generally quite good, with averages ranging from 48.7 to 80.3 per cent. In most instances low survivals could be attributed to areas of excessive acidity or extreme exposure.

5. Black locust was particularly outstanding in providing stabilization and cover on spoil bank areas. The average survival for locust plantings was 68.7 per cent, with many of the stands established on the more adverse portions of individual spoil areas. Eighty per cent of the black locust stands were rated as successful, while only 6.4 per cent of the stands were rated as failures.

6. Of the conifers planted on spoils in large numbers, the performances of Scotch pine, red pine, and white pine were particularly

good. Nearly 68 per cent of the conifer stands were rated as successful, while approximately 20 per cent were rated as partially successful, and only 12 per cent were designated as failures.

7. Survival of plantings was found to be closely correlated with precipitation during certain periods of the first growing season. Survival of black locust was most closely correlated with precipitation during the April to September period, while survival of conifers was most closely correlated with precipitation during the April to August period.

8. A definite correlation between slope and growth and survival of black locust plantings was noted. Survival was found to decline in direct relationship to increases in slopes per cent. Growth, on the other hand, was quite uniform on slopes up to 40 per cent and then declined as slopes increased above this point.

9. Changes in elevation were also found to affect the growth and survival of black locust plantings. Growth of black locust declined in direct relationship to increases in elevation, while survival was nearly constant at the lower elevations and then declined as elevation increased above 2,300 feet. Growth or survival of red and Scotch pines were not affected by changes in elevation.

10. Grading and its resulting compactions was found to affect the growth of plantings adversely but had little or no effect on survival.

11. Acidity of spoil material had a pronounced effect on the survival of plantings. On those areas having over one-half of their spoil material classified as toxic (pH less than 4.0), survival averaged less than 35 per cent; on sites with 25 to 50 per cent of their spoil material in the toxic class, survival averaged nearly 60 per cent; and on sites with less than one-fourth of their area in toxic class, survivals averaged better than 75 per cent. Fortunately, only a small proportion (8.2 per cent) of the spoil material sampled in this study fell into the toxic class.

12. Poor planting was observed to be a major cause of mortality and poor growth on many spoils, with numerous instances of "shovel root," planting too shallow, and planting too deep noted. Where spoil material is heavy or planting stock is large, it is probably best to use mattocks rather than planting bars for the planting operation.

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APPENDIX

COMMON AND TECHNICAL NAMES OF TREES

Common Name	Technical Name*
Birches	*Betula* spp.
Larch, European	*Larix decidua* Mill.
Locust, black	*Robina pseudoacacia* L.
Maples	*Acer* spp.
Pine, red	*Pinus resinosa* Ait.
Pine, Scotch	*Pinus sylvestris* L.
Pine, shortleaf	*Pinus echinata* Mill.
Pine, Virginia	*Pinus virginiana* Mill.
Pine, white	*Pinus strobus* L.
Poplars	*Populus* spp.
Spruce, Norway	*Picea abies* L.
Spruce, red	*Picea rubra* Link.
Sycamore	*Platinus occidentalis* L.
Yellow-Poplar	*Liriodendron tulipifera* L.

*Little, Elbert L., 1953. "Check List of Native and Naturalized Trees of the United States." Forest Service, U.S.D.A. Agricultural Handbook No. 41. 472 pp.

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